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Auroral Electrodynamics I:

1. Preliminary Electron Density Profile and, 2. Vehicle Potential Changes During an Active Beam Experiment.

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The report presents preliminary findings obtained by a pulsed plasma probe aboard a payload launched by a Terrier-Malemute sounding rocket from the Poker Flat Research Range. Results are obtlined both during passive and active (i.e., an Argon plasma gun) experiments.

Modifications to the design of the pulsed probe circuitry which allow tracking of the vehicle potential are described. The vehicle potential deduced from the analog records is plotted during times of interest (gun pulsing periods). An electron density profile with gun pulsing times indicated is also provided.

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AURORAL ELECTRODYNAMICS I:

1. Preliminary Electron Density Profile, and, 2. Vehicle Potential Changes During an Active Beam Experiment

I. INTRODUCTION

On January 27, 1980 at 09:17:00 UT a Terrier-Malemute sounding rocket launched a recoverable experimental payload from the Poker Flat Research Range at Fairbanks, Alaska. The purpose of the scientific investigation was a study of Ionosphere-Magnetosphere coupling employing measurements of precipitated and thermal particles and associated electric and magnetic fields. The single active experiment employed a beam of argon atoms at 30° to the payload axis to study the effects of the beam on the ambient plasma, particle distributions, and the vehicle potential.

The effort was a joint scientific investigation by the University of Minnesota, the University of New Hampshire and the Naval Research Laboratory. Figure 1 is a schematic of the payload configuration showing the location of the various experiments. In addition to the argon gun mentioned above were AC electric and magnetic field experiments (University of Minnesota), energetic particle detectors covering the range 0-10 Kev mounted at various angles with respect to the payload axis, and ion drift detector (University of New Hampshire). The NRL instrument was a

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pair of pulsed plasma probes for determining electron density, electron temperature, and power spectra of electron density fluctuations.

II. NRL EXPERIMENT

The NRL pulsed Langmuir probe system was developed to measure simultaneously both the plasma temperature (in the presence of time dependent plasma density change) and plasma density variations themselves. The basis of the pulsing technique and its design are to be found in earlier publications (Ref. 1-2).

The plasma probe system used in this flight, however, employed automatic sweep adjustment to track changes in vehicle potential. As can often happen, particularly where active experiments are concerned, one measures a shift in the vehicle potential. For example, in a recent series of beam-plasma experiments in the large vacuum chamber at Johnson Space Flight Center, significant "vehicle" potential shifts on the order of 5-7 volts were observed near the beam axis in the plasma. The plasma environment was similar to ionospheric conditions at 150 km. Experiments which hinge critically upon an accurate determination of this potential, or simply upon its constancy, can be seriously degraded without knowledge of the magnitude of the change. With the possible shift in vehicle potential in mind, a self-centering voltage sweep circuit was designed.

In addition to this improvement, the basic sampling rate provided in the telemetry format frame (Ref. 5) was increased by super commutation of the NRL outputs (i.e., 2 samples/subframe). During the fixed bias mode of the E-probe (biased to electron saturation) this increased output allows approximately 2500 samples/second of the electron density of the ambient plasma. The Nyquist frequency is therefore 1250 Hz which is approximately a factor of 4 increase over past performance. This frequency is critical when examining electron density fluctuation power spectra for interpretation of wave modes associated with the study of possible ionospheric instabilities.

The two probes in the NRL system are independent except for sweep envelope and pulse synchronization. The E-probe is pulsed to a symmetric sawtooth envelope from a baseline voltage of +4 volts. The pulsed sweep runs from -3 to +6 volts with the 100 usec sweep pulses occurring at a rate of 625 Hz. Eight symmetric sawtooth sweeps are alternated with eight sweep periods wherein no sweep pulses occur and the sweep voltage rests at the +5 volt baseline level. Thus, during pulsed sweeps, sweep data is taken at 625 Hz and baseline data at 1875 Hz. During the non-sweep period, all data is baseline data, and samples are taken at 1875 + 625 = 2500 Hz. (See timing diagram Figure 4.)

The I-probe sweep is pulsed uninterruped at 625 Hz. The pulses are time coincident with those of the E-probe (except that E-probe pulses are absent during alternate sets of 8 sweeps). The I-probe pulsed sweep envelope is symmetric like that of the E-probe. It's peak-to-peak amplitude is 5 volts. It's baseline, from which it is pulsed is .9 volts above the negative peak of the pulsed envelope. Circuitry in the self centering sweep probe electronics sets the value of the center-voltage of this I-probe sweep equal to the probe voltage required to produce zero probe-current. This is so that a complete Langmuir characteristic can be obtained under circumstances wherein the voltage of the space vehicle differs substantially from zero.

III. LAUNCH CONDITIONS

Pre-launch conditions were that the rocket should be launched into a fairly active aurora and if possible penetrate the Harang discontinuity (the boundary between the eastward and westward flowing electrojet). Conditions prevailing at the launch were partly a satisfactory fulfillment of these requirements. An active aurora (10-15 K Rayleigh in the 5577 A oxygen line) was observed both by Fort Yukon optical scanning photometers and photometers at the Poker Flat Optical Site. Magnetometers at both sites indicated a westward electron current (or eastward plasma flow). The H component of $\bar{B}$ deviated from quiet time readings between -100 γ to -200 γ at the Fort Yukon Site and approximately -60 γ to -80 γ at Poker Flat. In addition, Chatanika incoherent scatter radar measurements observed a southward electric field of approximately 10 mv/m 200 km north of Fort Yukon. These observations indicate that the Harang discontinuity was probably to the south of the Poker Flat range at launch time. These results are summarized in Table I.

IV. PRELIMINARY RESULTS

Figure 2 is a preliminary relative density profile for the upleg and downleg portions of the flight. (Notice that due to a timing malfunction on the nose cone release mechanism there is no data on the upleg below approximately 165 km.) This height profile is produced from one probe (E-probe) only and shows absolute electron density as calculated at four separate points along the trajectory. Although it is not strictly correct to deduce linearly other densities from the four given, one can nevertheless obtain an approximation within a factor of 2 to the electron density at any altitude in this manner. Preliminary analysis suggests there were no appreciable magnetic field effects (Reference (3)) on the baseline current measurements obtained by the probes until well after apogee. A modulation at approximately twice the roll frequency is apparent beginning at 560 sec. after liftoff. (It is also interesting to note that this modulation appears to increase during gun pulses. We are currently investigating this effect.) This is in keeping with the orientation of the probes with respect to the magnetic field. Reference (3) in fact shows that for an ionospheric plasma environment, magnetic field effects on cylindrical Langmuir probes should not become significant until the angle between the probe axis and the direction of $\bar{B}$ is $\lesssim 55^{\circ}$. At the preliminary densities calculated here, we find from

Figure (4) of Reference (3), Curve A that these effects will vary our baseline current measurements (from which density is calculated) by a factor of ~ .2 in the worst case. Since the probes are nearly perpendicular to $\bar{B}$ for a large portion of the flight, one expects any magnetic field effects to be minimal.

Because of the small effect of the ambient field on our current measurements and the relatively minor effects of the electrojet current on $|\bar{B}|$ in general, a crossing of the Harang discontinuity would not seem to produce a measureable effect on our results. In any case, our analysis of the analog data does not provide any information in this regard.

Although we noticed no large potential shifts during the first 5 Ar gun pulses, we did notice a 9 volt negative shift during the sixth (616-624.5 sec) "gun-on" period (Figure 3). The absolute magnitudes of the potential changes in Figure (3) are not final and should not be relied upon to more accuracy than $\pm$ 1/2 volt. The shift indicated by our I-probe self-centering sweep circuit is verified by the behavior of the E-probe during the gun pulse periods. The E-probe shows no significant collection of ion current in its constant bias mode (V_B = + 4 Volts) until the sixth gun pulse and directly after as in Figure 3. This is consistent with a large (>|-4| Volts) vehicle potential change.

The vehicle potential shift then appears to be correlated to the "turn-on" of the argon gun. However, the lack of a significant shift during the first 5 pulses is somewhat puzzling. An altitude (i.e., ambient plasma density) effect or the presence of electron streaming at higher altitudes occur as possible conditions to consider in these observations. Correlations among experimenters will be useful in this regard.

Evidences of increased ambient temperatures, mean ion mass fluctuations, as well as plasma wave modes which might be present in electron density fluctuation power spectra must await more complete data reduction and analysis. Therefore, any conclusions to be drawn regarding the central issues of energetic particle coupling to the ambient plasma during an aurora, or possible instabilities triggered during gun pulses will necessarily be forthcoming at a later time.

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TABLE I

LAUNCH CONDITIONS AND TRAJECTORY INFORMATION

LAUNCH TIME	0917 UT, 27 JAN 1980
PAYLOAD WEIGHT	390 Lbs.
APOGEE	432 Km
RANGE	380 Km
SPIN RATE	3.5 CPS
LAUNCH Q.E.	80.5°
LAUNCH AZ	28°
EMISSION INTENSITIES	$\sim$ 10 KR 5577 A at Poker $\sim$ 15 KR 5577 A at Fort Yukon
MAGNETIC FIELD INTENSITY DEVIATION FROM QUIET TIME	$\left.\begin{array}{l}\Delta H \sim -72\ \gamma \\ \Delta Z \sim -40\ \gamma\end{array}\right\}$ Poker $\left.\begin{array}{l}\Delta H \sim -120\ \gamma \\ \Delta Z \sim -50\ \gamma\end{array}\right\}$ Fort Yukon

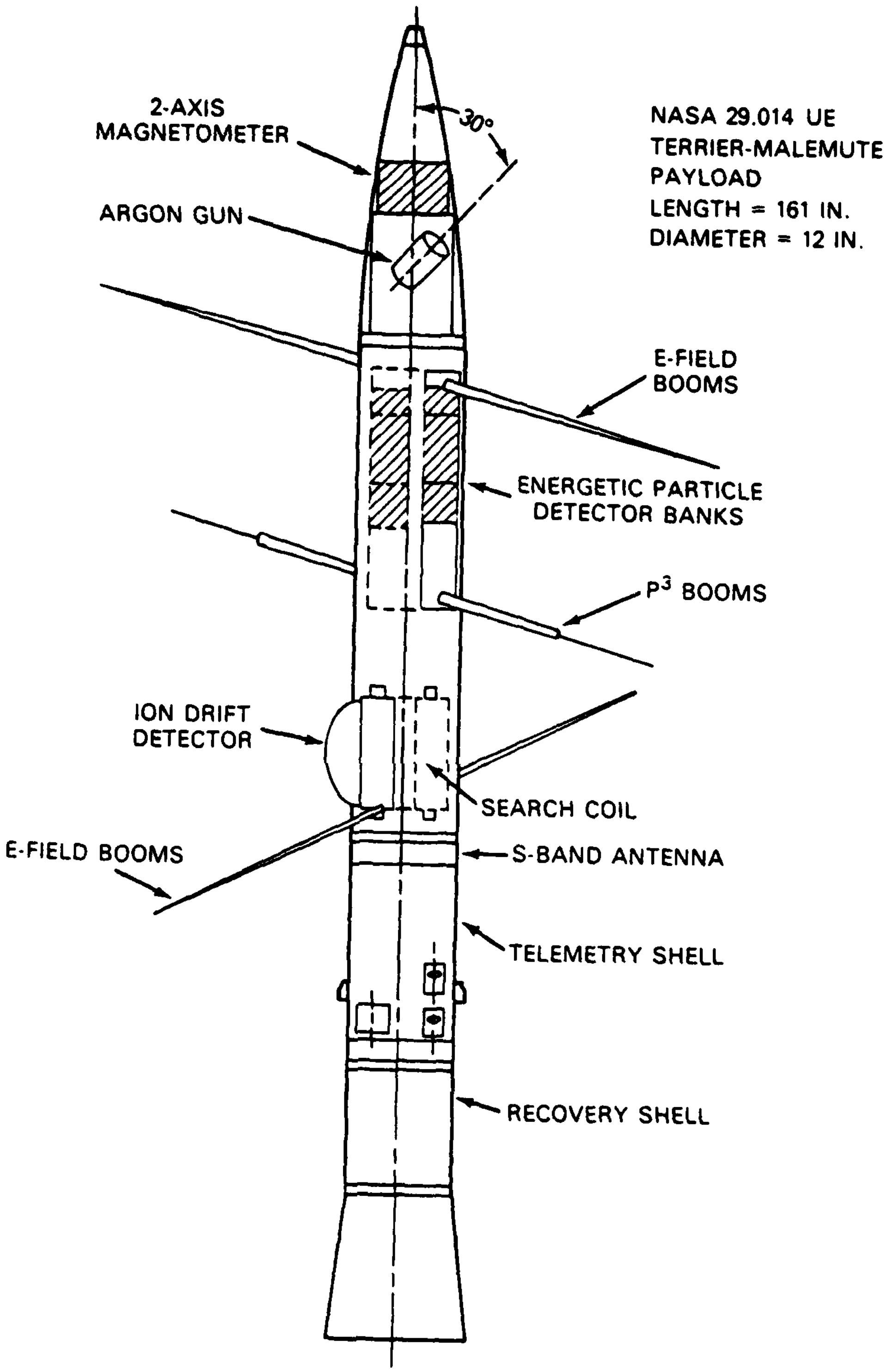
2-AXIS
MAGNETOMETER
30°
NASA 29.014 UE
TERRIER-MALEMUTE
PAYLOAD
LENGTH = 161 IN.
DIAMETER = 12 IN.
ARGON GUN
E-FIELD
BOOMS
ENERGETIC PARTICLE
DETECTOR BANKS
P3 BOOMS
ION DRIFT
DETECTOR
SEARCH COIL
E-FIELD BOOMS
S-BAND ANTENNA
TELEMETRY SHELL
RECOVERY SHELL

Fig. 1

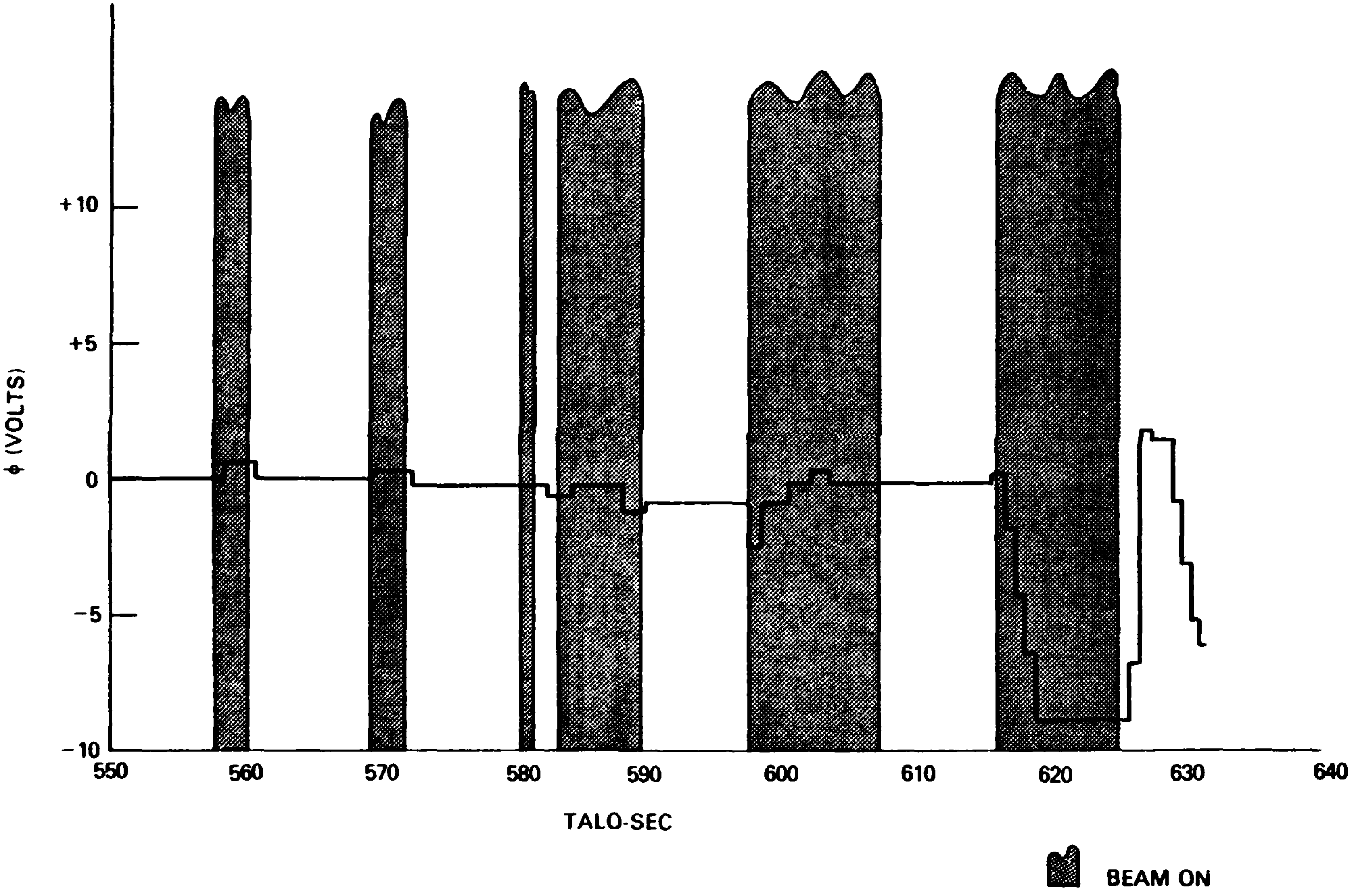

Fig. 2 - Preliminary relative electron density profile NRL pulsed plasma probe

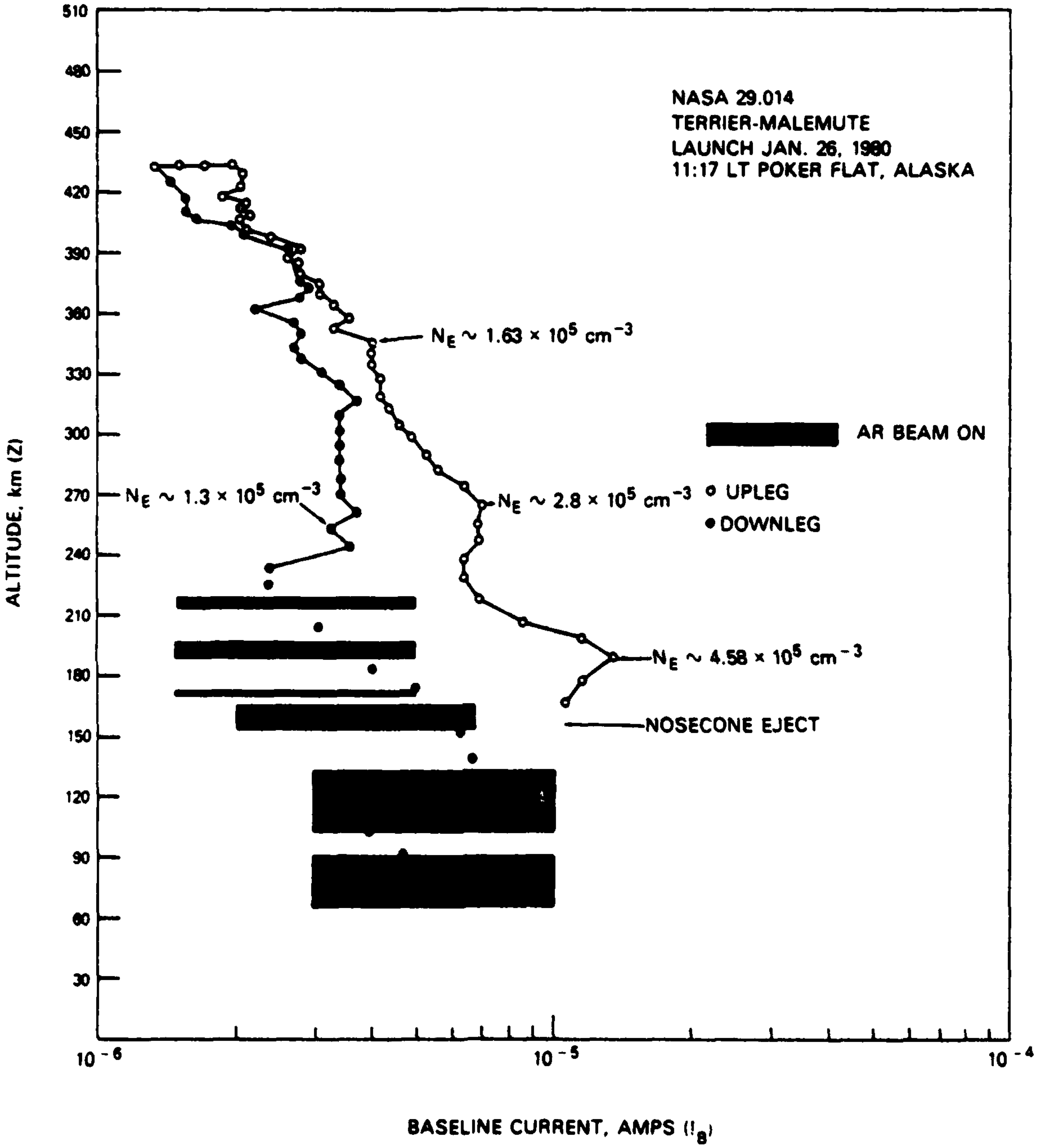

Fig. 3 - Vehicle potential during "Gun On" periods deduced from P^3 circuit

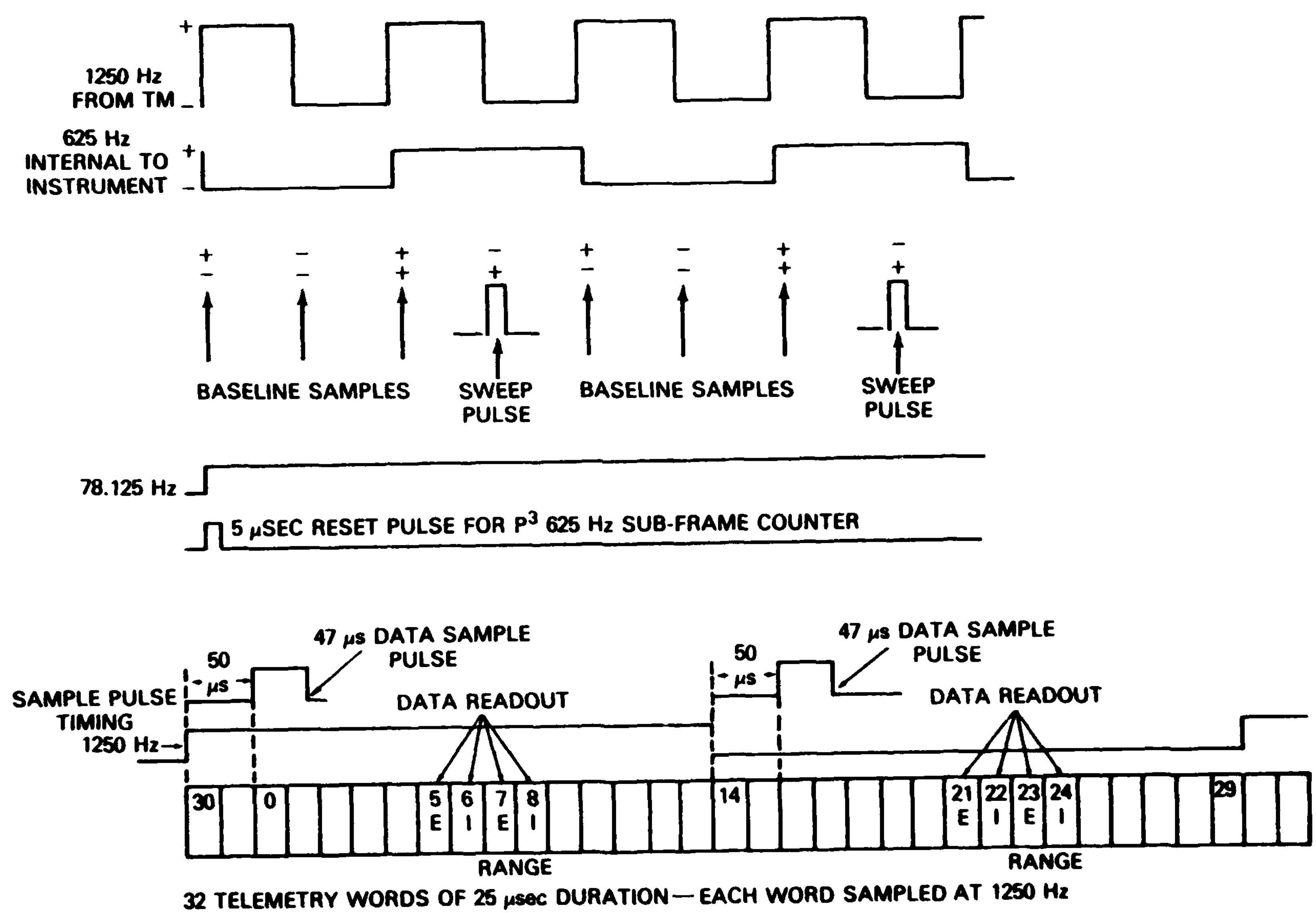

Fig. 4 - Auroral electrodynamics basic timing diagram (P^3)